RESEARCH INFRASTRUCTURES FOR CULTURAL HERITAGE: A ROADMAP IN THE MAKING

C. Andreani
Università degli Studi di Roma Tor Vergata, Dipartimento di Fisica, Via della Ricerca Scientifica 1, 00133 Roma, Italy

F. Zanini
Sincrotrone Trieste, S.S. 14 Km 163,5 in Area Science Park, 34012 Basovizza-Trieste Italy

W.A. Kockelmann, P.G. Radaelli
ISIS Facility, Rutherford Appleton Laboratory, Chilton, Didcot, Oxfordshire, OX11 0QX, UK

RICH (Research Infrastructure for Cultural Heritage), http://neutron.neutron-eu.net/n_nmi3/n_networking_activities/rich is the name of a new initiative to bring the worlds of multi-disciplinary research and Cultural Heritage closer together. The initiative is promoted at the European level by Research Infrastructures, scientific institutions, research councils and universities, and has been launched by an International Workshop, that has taken place on December 12 and 13 in Trieste (Italy), at the Abdus Salam International Centre for Theoretical Physics (ICTP). The meeting was co-organised by the three European Integrated Infrastructure Initiatives (I3) that promote the development of large-scale facilities (LSFs) in the fields of neutrons (nmI3), synchrotron X-rays (IA-SFS) and lasers (Laserlab Europe) and by EU-ARTEC, an I3 consortium operating in the field of artwork conservation. The RICH workshop was sponsored and supported by a large number of universities, central facilities and institutions across Europe, and generously hosted by ICTP. The stated aim of RICH was to survey the established research and the most promising lines of technical developments, with the goal of creating a portfolio of LSFs-based techniques that could effectively complement the well-established portable and laboratory-based tools for assignment, conservation and restoration of historical and artistic objects. In preparation of the RICH workshop of December 2005, a preliminary study meeting was held on October 5, 2005 in Rome, generously hosted at Istituto Sturzo, Palazzo Baldassini, Roma and organised by Andrea Granelli (Fondazione COTEC), where working groups of invited experts in the fields of "Cultural Heritage" and "Research Infrastructures" contributed to shape the structure and the contents of the December meeting.

During the first day of the workshop, a cross-section of the programmes currently active at LSFs in the field of CH, using, for example, synchrotron-based spectroscopy and diffraction, neutron activation and neutron diffraction, as well as specialised laser techniques, was effectively compared and contrasted with the experience matured over several years if not decades with the use of ion beam techniques and light spectroscopy in the assessment of historical artefacts. This was also an opportunity for the delegates to present some of their latest results, in a vibrant, multi-disciplinary atmosphere, where both oral and poster presentation received plenty of constructive feedback.

Some of the characterisation methods employed at LSFs have achieved a high degree of sophistication while others are still being developed. Not surprisingly, a re-occurring topic throughout the day was the non-destructiveness of the various techniques and probes. It is widely accepted that any examination method inescapably changes the sample in one way or another, even though the sample alterations may be undetectable with present-day scientific methods. Whether one addresses problems in archaeology and conservation with traditional destructive examination methods, micro-destructive techniques or "non-destructive" methods remains to be decided on a case by case basis. However, many objects of art and archaeology would never be examined if it was not for the non-invasive examination techniques.

The talks covered a wide range of established and emerging applications of synchrotron, neutron and laser radiation in Cultural Heritage and archaeological sciences. In his presentation on imaging methods, Eberhard Lehmann (Paul Scherrer Institute, Villingen, Switzerland) focused on neutron radiography and neutron tomography applications, although always emphasizing the strengths of the complementary of neutron and X-ray imaging techniques. In many cases, both neutron and X-ray radiographies are required to obtain a full 'picture' of the object. The tomographies, mostly on objects from the Swiss National Museum and Swiss private collections, were obtained on the neutron tomography set-up at the Paul Scherrer Institute and covered aspects of authentication (helmet reconstruction from Gubiasco), making techniques ('Merkur from Uster'), and conservation (in-situ imaging of infiltration of resin into wooden objects). Magnificent neutron tomographies, recently collected from bronze statues from the Rijksmuseum Amsterdam, highlighted the amazing imaging capabilities with state-of-the-art hardware and software. Costing and safety issues related to the transport, insurance and

transportation of objects were also discussed.
Roberto Triolo (University of Palermo, Italy) introduced rather novel examination methods, namely small (SANS) and ultra-small (USANS) angle neutron scattering, on white and polychrome marble used in ancient monuments and works of art for the purpose of tracing their provenance. These methods provide information on the 'mesoscopic' structure of marbles, in terms of particle or pore sizes and fractal geometries, which are often related to the metamorphic changes during formation, and hence, to the site of formation. Different grades of metamorphism, and thus, 'low and high' quality marble can be distinguished by looking at the building blocks, as demonstrated mostly on marble samples from Villa Adriana (Tivoli, Rome), also in relation with neutron tomographic images, obtained on the same samples at the Berlin neutron centre BENSC.
The next talk of the session by Birgit Schroeder-Schmeibidl (Hahn-Meitner Institute Berlin, Germany) was on neutron autoradiography, a fine technique to reveal different pigment and paint layers piled-up during the creation of a painting. In many cases the individual brushstrokes applied by the artist are revealed, as well as changes made during the painting process (the so-called *pentimenti*). Neutron autoradiographs may be used in support of restoration interventions, as it was demonstrated for 'The baptism of a Child' (Jan Steen, 17th century). Many *pentimenti* were revealed, indicating that Steen has painted over a picture with completely different content. In another case of authentication, 'The Hermit', a work of art of an unknown artist but suspected to be made by the hand of Rembrandt, no modern pigments and no contradiction to the works of Rembrandt were found. However, the structural features are in remarkable agreement with the 'handwriting' of the 17th century Dutch painter Govaert Flinck.
Gianluca Valentini (Politecnico di Milano, Italy) presented a totally different method for pigment identification, this time on marble sculptures, exploiting the fluorescence emission of UV laser excitation. A portable system allows one to produce spatial maps of pigments and contaminants such as wax, oxalates and cast residues even for multi-component mixtures. Complementary images can be produced by time-gated amplitude and life-time fluorimetry. The technique was used to survey marble sculptures such as the Michelangelo's 'David' (Florence) and the Pietà Rondanini (Milan) before and after cleaning procedures.
Gerard Sliwinski (Polish Academy of Sciences, Poland) reported on the Pomeranian Laser Laboratory in Gdansk, which focuses on Cultural Heritage research since 1998. Lasers are used for both artwork restoration and for conservation treatments, as well as for non-destructive identification and composition analysis of surface layers such as contaminants, substrate and pigments. The case studies presented at RICH included Godlandic Sandstone from the Baltic sea, historical paper documents, silver coins from Pomeranian museums, and pigment identification on a 15th century wooden crucifix.
Berta Guzman de-la-Mata (University of Warwick, UK) presented results on corrosion studies of rough, heterogeneous metal surfaces, as encountered in 'real' archaeological artefacts. The results were obtained with a new electro-chemical cell that was specifically developed (with support from COST-G8) for use on synchrotron beamlines. In-situ studies of electrochemical processes as they occur are important in developing and understanding potential conservation and stabilization treatments, and may be extended to study corrosion processes themselves. The first results of the combined electrochemical and SR-XRD study of copper objects exposed to sea water at the SRS at Daresbury were presented, demonstrating conversion of the 'non-passivating' nanatokite to the more protective corrosion phase cuprite during storage in sodium sesquicarbonate.
Birgit Kanngiesser (TU Berlin, Germany) presented a series of applications of micro-X-ray fluorescence (micro-XRF), which is able to reveal oxidation and migration processes of inorganic compounds in ink-corroded manuscripts. These non-destructive investigations are of great importance for understanding complex paper degradation processes. The latest development on portable micro-XRF, spatial mapping of Fe^{2+}/Fe^{3+} ratios by micro-XANES and of a new 3D micro-XRF mapping instrument were presented. Examples included analyses of a manuscript of the 'magic flute', fragments of Goethe's 'Faust', and Dürer's 'sketchbook'. Trace element analyses of the gold stars on the Nebra skydisk were also presented.
Pier Andrea Mandò (University of Florence, Italy) introduced the LABEC Florence accelerator laboratory for ion beam analysis (IBA) and accelerator mass spectrometry (AMS) for radiocarbon dating. The new laboratory, which was opened in 2004, is capitalising on previous successes

in the solution of important problems, like the chronological reconstruction of undated Galileo's handwritten notes using the ink composition as a dating criterion.
In the afternoon session, Salvatore Siano (CNR Florence, Italy) gave a comprehensive overview of current laser technologies and neutron diffraction techniques in Cultural Heritage. Conservation interventions by laser techniques on ancient artefacts such as the Minerva from Arezzo and the Treasure of Rimigliano, as well as the Gate of Paradise were presented. These interventions are complemented by both traditional and novel metallurgical studies to provide the basic knowledge on the development of art and fabrication techniques. The first pioneering and systematic neutron-metallurgical investigations of a number of Etruscan, Picenan and Roman objects were presented. Time of flight neutron diffraction at the ISIS facility in the UK was used to non-destructively characterise the objects in terms of the structure properties, i.e. phase distributions, crystallographic textures and macrostrains. A lively discussion after this talk centered on the non-invasiveness of the neutron methods. It was commented that irradiation with neutrons compromises the thermoluminescense dating. A proposal for an experiment to study the effects of neutron irradiation on dating results was made, by considering both high-flux exposures typically done for neutron activation analyses, and low-flux irradiation on present-day neutron beamlines for tomography, gamma spectroscopy and diffraction.
L. Cartechini (University of Perugia, Italy) followed with a talk on time-of-flight neutron diffraction applications at the ISIS spallation neutron source. After an overview on the capabilities and limitations of neutron diffraction, results on three 17th to 12th BC century bronze axes from the Terremare settlements near Modena (Italy) were presented. Neutron diffraction elegantly and non-invasively provided a differentiation of the three objects in terms of phase compositions, microstrains and texture, properties which are related to the material treatment during fabrication or use.
Roxana Bugoi (National Institute of Nuclear Physics, Bucarest, Romania) presented a micro-XRF study of metal inclusions (e.g. platinum) in archaeological gold with a detailed description of the optimisation measures for the trace element analysis set-up at the ANKA synchrotron source at Karlsruhe, Germany. Results from several ancient gold objects from the Visigothic Pietroasa treasure were presented, along with data from natural gold samples from Transylvania.
Massimo Rogante (NDT, Civitanova, Italy) concluded the session by presenting results on Iron Age bronze, iron and pottery objects from a Picenan necropolis of Centre Italy studied with prompt gamma activation analysis (PGAA), an important tool for non-destructive bulk elemental analysis. Both major and trace elements were determined by PGAA and used for a classification of the objects.
An afternoon poster session with about 30 contributions concluded this 'science and techniques' day of the workshop. The poster session gave many participants the possibility to report on latest accomplishments and highlights of ongoing projects. All contributors to the Oral and Poster sessions of the meeting are invited to submit their contribution a part of the Workshop Proceedings, which will be subject to peer review and published in a special issue of the Nuovo Cimento C.
In spite of the obvious differences in scale (which ranged from the suitcase to the synchrotron) and, consequently, the mobility of the equipment described by the delegates, a number of common themes clearly emerged, and in particular, the need to establish an effective partnership between art historians, materials scientists and instrument scientist, with the museum-based research conservators playing a pivotal role. These themes were expanded during the second day with two sessions on "governance" and "the broader perspective", followed by a round-table discussion. Costas Fotakis (IESL – FORTH, Heraklion, Greece) stated quite convincingly that the European way is the one to follow. there is a clear added value from a pan-European initiative, in that there is often a geographical separation between the richest collections of historical artefacts and work of arts, the university departments and research councils that have already overcome the "language barrier" with the humanists and possess the expertise with the applied materials science and the more "conventional" techniques, and the large-scale, multi-disciplinary facilities. Costas concluded by illustrating the recent achievements of a pan-European collaboration, COIST-G7, centred on laser techniques (LIDAR mapping, spectroscopy and fluorescence analysis and laser restoration).
Jana Kolar (National and University Library of Slovenia, Lubjana) illustrated the key ingredients that must be put in place if a wider initiative is to be successful. The economic arguments were particularly compelling: in Europe, CH generates and annual income of 335,000M€, and 14,000 M€/years are effectively lost due to the degradation of the artistic patrimony, in addition to the irreparable loss of often unique artefacts. But what are the key elements of a future "European infrastructure"? Providing access to the LSFs was clearly identified as a central issue. Moreover, the management of this access will have to recognise the uniqueness of the CH field, not only in identifying appropriate ancillary facilities, for example, for the handling and storage of the artefacts, but also in providing dedicated peer review mechanism to assess the proposed work in the appropriate context.
Jean-Louis Boutaine (C2RMF, EU-ARTECH, Paris,

France) and Hannelore Römich (COST office, European Science Foundation, Brussels, Belgium) invited us to avoid the tropisms of "aristocratic physics" and "aristocratic art history", and to consider the impact on the long-term viability of the collections, rather than simply the public relation aspect. In practical terms, this translates in providing, first of all, accurate information on the capabilities (and limitations) of each techniques, a competent, dedicated team of experts and reliable "routine" access rather than a series of "one-off" experiments. We must also "look in the neighbourhood", and take advantage of the vast capital of experiences developed by existing initiatives such as COST-G7, COST-G8 and EU-ARTECH. After all, CH research at LSFs is a growing field, but it is still a small fraction of the work involving science and technology for the comprehension and conservation of the European Cultural Heritage, as recently "photographed" in a report produced by the Labs Tech initiative.

An example of European involvement in this area, and a useful model for future expansion, is represented by the ANCIENT CHARM initiative, presented by Giuseppe Gorini (University of Milano-Bicocca, Italy). ANCIENT CHARM is the result of a collaboration between 10 universities, central laboratories and museum institutions across Europe, and is now a EU funded ADVENTURE project under the New and Emerging Science and Technology (NEST) programme of FP6. The central goal of ANCIENT CHARM is to develop an imaging technique based on Neutron Resonant Capture, but complementary diffraction/transmission-based imaging techniques will also be developed in parallel.

EU-ARTECH, as presented by Antonio Sgamellotti (University of Perugia, Italy) is another particularly relevant piece of this complex "patchwork" of existing and emerging activities, in that it represents a successful EU initiative to support access, networking and research related to existing infrastructures in the field of ion beam analysis and mobile laboratory technology. Antonio underlined the difficulty in persuading Brussels that this collection of techniques is indeed an "infrastructure", but stressed, at the same time, the value of a technology that "goes to the users".

Conversely, the unique issues associated with bringing artwork and expertise to the LSFs sites must be addressed if the powerful techniques available at LSFs are to become a routine tool in CH research. Loïc Bertrand (Synchrotron SOLEIL, France) illustrated in detail the proposed scheme for a dedicated CH "interface" that will be activated at the SOLEIL Synchrotron facility, to become operational in 2007. Preparatory work for this "interface" has already commenced, with a small amount of staff being involved in surveying the user base and defining the science portfolio and the access mechanisms, as well as in providing training activities for the users. The "interface" issue was to become the centrepiece of the final part of the meeting. The model proposed by Loïc involves a relatively small amount of dedicated staff at the LSFs, with the "institutional" CH laboratories providing the main link with the museums. Further down the line, the gradual development of standardise protocols would enable the museums to access LSFs directly. Robert van Langh (Rijksmuseum - Amsterdam, The Netherlands) presented a different model, pointing out that a number of museums already have research-based conservation departments, and that research conservators have shown to be quite capable of interfacing directly with the facilities. This was illustrated by drawing from Robert's recent neutron work on a bronze statuette collection from the Rijksmuseum, which also featured very prominently in Eberhard Lehmann's talk on day 1 and in a poster presented by Dirk Visser. For a more effective use of the LSFs, research conservators would need to interact with larger, dedicated teams of scientists based at LSFs, rather than with liaison officers or individual instrument scientists.

All these points were again touched upon during the Round Table discussion, with particular emphasis on networking, communication, training and access. Claudio Tuniz (The Abdus Salam ICTP, Trieste, Italy) and Wegrzynek Dariusz (The IAEA Seiberdorf, Austria) stressed the need to look beyond Europe and towards the rich cultural and technical reservoir in the developing countries, emphasizing the role that institutions such as the ICTP, UNESCO and IAEA could play in this context. The workshop was concluded by agreeing on a list of actions. First of all, the organising committee pledged to complete the original RICH objectives, which were focused on advising the LSFs and their supporting I3 on the best provisions to support current and future CH work. In this, the foresight study questionnaire, to be completed by all participants, should prove an invaluable tool. Specific recommendations will also be issued on the courses of actions to be taken vis-à-vis the provision of non-virtual LSFs-based interface/support units, the possible launch of a "horizontal" I3 initiative in FP7 to provide specific access, networking and research and on the blueprint for a possible new "research infrastructure" beyond FP7. In the meantime, one of the main objectives of RICH has already been brilliantly achieved: four different communities working with neutrons, lasers, synchrotron and "conventional" techniques, traditionally used to walk their separate ways, have started talking to each other and with the museum-based research conservators. Let us interpret this as a good omen for a "RICH" and productive continuing cooperation for the understanding and preservation of our common European heritage.